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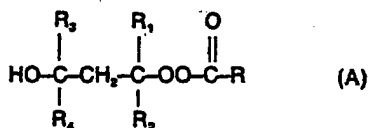
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54 Hydroxy-t-alkyl peroxyester.

57 Hydroxy-t-alkyl peroxyesters having the general structure



where R, R₁, R₂, R₃ and R₄ can be alkyl moieties and having 10 hour half-life temperatures below about 75°C (for example, 3-hydroxy-1,1-dimethylbutyl peroxy-neodecanoate) are described. These peroxyesters are used as initiators for vinyl monomer polymerization and as catalysts for curing unsaturated polyester resins in order to improve the efficiency of the systems.

Hydroxy-t-Alkyl PeroxyesterBackground of the Invention

This invention relates to novel hydroxy-t-alkyl
5 peroxyesters (A) and the use of these compositions as free-radical initiators for improved vinyl monomer polymerization processes and as curing catalysts for improved unsaturated polyester resin curing processes.

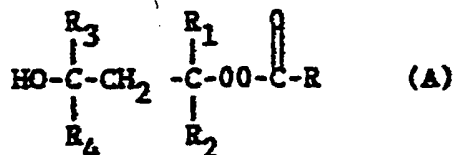
From an economic standpoint the polymer industry wishes
10 to increase production of polymeric resins without resorting to building additional expensive production facilities. It is well known in the polymerizations arts, especially in the art of polymerizing vinyl chloride, that rates of polymerizations can be enhanced by using more active free-radical

catalysts; thus, polymerization cycle times can be decreased and production capacity can be increased when this technique is employed. This phenomenon is especially useful in vinyl chloride polymerizations, since more active catalysts result in higher polymerization rates without simultaneously affecting polymer molecular weight characteristics (assuming that the temperature is not changed); hence, polymer physical properties remain unchanged. It is, also, well known in the peroxide art that half-life characteristic (a measure of peroxide activity) of peroxides can be changed significantly for certain classes of peroxides by employing various structural changes in the peroxide.

The hydroxy-t-alkyl peroxyesters of the present invention have been found to improve the efficiency of polymerization systems using lesser amounts of the initiator than were used in the prior art. The 10 hour half-life temperatures of compounds of the present invention are significantly decreased over similar prior art peroxyesters.

Summary of the Invention

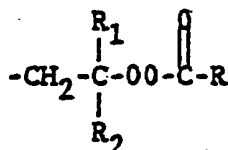
The present invention is directed to
A) A hydroxy-t-alkyl peroxyester of structure (A)



which has a 10 hour half-life temperature below about 75°C,
where

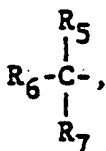
R_1 and R_2 are selected from an alkyl of 1 to 4 carbons,
 R_3 and R_4 are selected from hydrogen or an alkyl of 1 to
4 carbons,

R_1 and R_3 can be connected together to form a lower
alkyl substituted 3 carbon alkylene bridge and R_3 can
additionally be



and

R is selected from



or



where

R_5 is selected from hydrogen or an alkyl of 1 to 8
carbons,

R_6 is selected from an alkyl of 1 to 8 carbons,

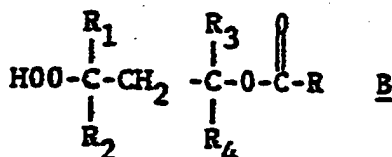
R_7 is selected from the group consisting of an alkyl of
1 to 8 carbons, an alkenyl of 1 to 8 carbons, an aryl of 6 to
10 carbons, an alkoxy of 1 to 6 carbons and an aryloxy of 6
to 10 carbons, and

- R_8 and R_9 are selected from an alkyl 1 to 4 carbons;
- B) A process of polymerizing ethylenically unsaturated monomers (such as ethylene and vinyl chloride) by using an initiating amount of the hydroxy-t-alkyl peroxyester of structure A as the initiator at appropriate temperature during the polymerization; and
- C) A process of curing unsaturated polyester resin compositions by heating such resins in the presence of a catalyzing amount of A as the curing agents.

DETAILED DESCRIPTION OF THE INVENTION

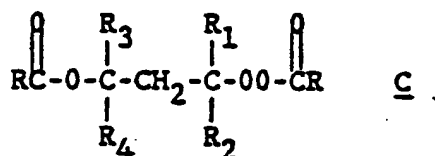
Preparations of the Hydroxy-t-Alkyl Peroxyesters

The hydroxy-t-alkyl peroxyesters (A) of this invention can be prepared by reacting an appropriate acid chloride, acid bromide or acid anhydride with a hydroxy-t-alkyl hydroperoxide in the presence of a base and optionally in the presence of a phase transfer catalyst (PTC). Surprisingly the acylation reaction predominantly occurs at the hydroperoxy group rather than at the hydroxy group of the hydroxy-t-alkyl hydroperoxide, thus forming the invention hydroxy-t-alkyl peroxyesters A rather than hydroperoxy-alkyl esters B. Some further reaction of A with the acylating



agent can occur to produce small amounts of ester-t-alkyl peroxyester C. C could also be produced to a small extent by further reaction

5



of B (if it formed) with acylating agent. In general, the acid chlorides employed for producing the hydroxy-t-alkyl peroxyesters of this invention are sterically hindered acid chlorides which readily react at the hydroperoxy group of the hydroxy-t-alkyl hydroperoxide but much less readily react at the hydroxy group of the hydroxy-t-alkyl hydroperoxide or at the hydroxyl group of A. Such hindered acid chlorides are derived from hindered di- and tri- α -branched carboxylic acids that are listed further below. Less sterically hindered acid chlorides, such as those derived from non- and mono- α -branched carboxylic acids and aromatic carboxylic acids readily react with the hydroxy group of the hydroxy-t-alkyl peroxyester (see Example 17, *infra*). The invention hydroxy-t-alkyl peroxyesters of this invention are restricted to those derived from sterically hindered acid chlorides as defined above. This puts an upper 10 hour half-life temperature limit of about 75°C on the invention hydroxy-t-alkyl peroxyesters since none of the higher temperature

invention hydroxy-t-alkyl peroxyesters, 3-hydroxy-1,1-dimethylbutyl peroxy-(2-ethylhexanoate), had a 10 hour half-life temperature of about 66-67°C. The non-invention hydroxy-t-alkyl peroxyesters that are derived from less hindered acid chlorides generally would have 10 hour half-life temperatures of about 90 to 100°C (if they could be made). Hence, the invention hydroxy-t-alkyl peroxyesters (Structure A) are much more active in initiating polymerizations of ethylenically unsaturated monomers and in curing of unsaturated polyester resins. The preferred acid chlorides can be prepared from the corresponding acid by reacting with acid chlorinating agents such as PCl_3 , POCl_3 , PCl_5 , SOCl_2 , phosgene (in the presence of *N,N*-dimethylformamide) and benzotrichloride followed by isolation of the acid chloride product from the reaction mixture.

Carboxylic acids that are useful for producing the hydroxy-t-alkyl peroxyester A of this invention include alkylarylacetic acids such as 2-phenylpropionic acid 2-phenylbutyric acid, and 2-methyl-2-phenylpropionic acid, alkoxypropionic acids such as 2-methoxypropionic acid, aryloxypropionic acids such as 2-phenoxypropionic acid, unsaturated carboxylic acids such as methacrylic acid and 2-methyl-2-butenic acid, α,α -dialkylacetic acids such as is butyric acid, 2-ethylbutyric acid, 2-ethylhexanoic acid, and 2-butyloctanoic acid and α,α,α -trialkylacetic acids (i.e., ne acids) such as pivalic acid, neohexanoic acid,

neohexanoic acid, neooctanoic acid, neononanoic acid, neodecanoic acid and neotridecanoic acid (the compositions and structures of the latter five neoacid mixtures being those described in U.S. Patent 3,624,123).

5 Hydroxy-t-alkyl hydroperoxides that are useful for producing the hydroxy-t-alkyl peroxyesters A of this invention include 3-hydroxy-1,1-dimethylpropyl hydroperoxide, 3-hydroxy-1,1-dimethylbutyl hydroperoxide, 1-ethyl-3-hydroxy-1-methylpentyl hydroperoxide, 1,1-
10 diethyl-3-hydroxybutyl hydroperoxide, 5-hydroxy-1,3,3-trimethylcyclohexyl hydroperoxide and 4-hydroxy-2,6-dimethyl-2,6-dihydroperoxyheptane. The hydroxy-t-alkyl hydroperoxides can be prepared by treating the corresponding hydroxy-t-alkanols with excess hydrogen peroxide in the
15 presence of a strong acid catalyst such as sulfuric acid, phosphoric acid, perchloric acid, the acid form of an ion exchange resin or *p*-toluenesulfonic acid. For instance, 1,1-dimethyl-3-hydroxybutyl hydroperoxide, also known as
hexylene glycol hydroperoxide, has been prepared in this
20 manner from commercially available 2-methyl-2,4-pentanediol (hexylene glycol) according to U.S. Patent 3,236,072. The hydroxy-t-alkanols which are used to prepare the hydroxy-t-alkyl hydroperoxides can be prepared by methods well known in the art. For instance, some hydroxy-t-alkanols can be
25 prepared by treating lactones with a Grignard agent (e.g.,

methylmagnesium bromide). The hydroxy-t-alkyl hydroperoxides can also be prepared using the corresponding hydroxy-t-alkylene in place of the hydroxy-t-alkanols. Thus, treatment of a hydroxy-t-alkylene with hydrogen
5 peroxide in the presence of a strong acid catalyst results in formation of the hydroxy-t-alkyl hydroperoxide.

The bases that are useful in preparing the hydroxy-t-alkyl peroxyesters A of this invention include inorganic bases such as NaOH, KOH, LiOH, Na₂CO₃ and K₂CO₃
10 and organic amines such as pyridine, N,N-dimethylaniline, triethylamine, tributylamine and 1,4-diazabicyclo [2.2.2] octane. The optionally employed phase transfer catalysts include tetraalkylammonium salts such as tetrabutylammonium chloride, bromide and hydrogen sulfate and other reported
15 phase transfer catalysts.

Representatives of the hydroxy-t-alkyl peroxyester A of this invention are as follows:

- 3-Hydroxy-1,1-dimethylbutyl peroxy-2-phenylbutyrate,
- 3-Hydroxy-1,1-dimethylbutyl peroxy-2-phenoxypropionate,
- 20 3-Hydroxy-1,1-dimethylbutyl peroxymethacrylate,
- 3-Hydroxy-1,1-dimethylbutyl peroxy-2-methylcrotonate,
- 3-Hydroxy-1,1-dimethylbutyl peroxyisobutyrate,
- 3-Hydroxy-1,1-dimethylbutyl peroxy-(2-ethylhexanoate),
- 3-Hydroxy-1,1-dimethylbutyl peroxy-(2-butyl octanoate),
- 25 3-Hydroxy-1,1-dimethylbutyl peroxy-pivalate,

- 3-Hydroxy-1,1-dimethylbutyl peroxyneohexanoate,
3-Hydroxy-1,1-dimethylbutyl peroxyneoheptanoate,
3-Hydroxy-1,1-dimethylbutyl peroxyneodecanoate,
3-Hydroxy-1,1-dimethylbutyl peroxyneotridecanoate,
5 3-Hydroxy-1,1-dimethylpropyl peroxyneohexanoate,
3-Hydroxy-1,1-dimethylpropyl peroxyneodecanoate,
3-Hydroxy-1,1-dimethylpropyl peroxyneopivalate,
3-Hydroxy-1,1-diethylbutyl peroxyneohexanoate,
5-Hydroxy-1,3,3-trimethylcyclohexyl peroxyneodecanoate,
10 4-Hydroxy-2,6-dimethyl-2,6-di(neohexanoylperoxy)heptane,
and
4-Hydroxy-2,6-dimethyl-2,6-di(neodecanoylperoxy)heptane.

Vinyl Polymerizations

15 In the free-radical polymerizations or copolymerizations
of ethylenically unsaturated monomer at suitable temperatures
(and pressures) the hydroxy-t-alkyl peroxyesters A of this
invention are found to be efficient initiators (i.e., reduced
initiator requirements).

20 Ethylenically unsaturated monomers include olefins, such
as ethylene, propylene, styrene, alpha-methylstyrene, chloro-
styrene, vinyltoluene, vinylbenzyl chloride, vinylpyridine
and divinylbenzene; di lefins, such as 1,3-butadiene,
isoprene and chloroprene; vinyl esters, such as vinyl
acetate, vinyl propionate, vinyl laurate, vinyl benzoate
25 and divinyl carbonate; unsaturated nitriles, such as
acrylonitrile and methacrylonitrile; acrylic acid,

methacrylic acid and their esters and amides, such as methyl, ethyl, n-butyl and 2-ethylhexyl acrylates and methacrylates, and acrylamide and methacrylamide; maleic anhydride; maleic and fumaric acids and their esters; vinyl halo and vinylidene
5 halo compounds, such as, vinyl chloride, vinyl bromide, vinyl fluoride, vinylidene chloride and vinylidene fluoride; perhalo olefins, such as tetrafluoroethylene, hexafluoropropylene and chlorotrifluoroethylene; vinyl
ethers, such as methyl vinyl ether, ethyl vinyl ether and
10 n-butyl vinyl ether; allyl esters, such as allyl acetate, allyl benzoate, diallyl phthalate, allyl ethyl carbonate, triallyl phosphate, diallyl fumarate and diallyl carbonate; acrolein; methyl vinyl ketone; and mixtures thereof.

In this invention temperatures of 20°C to 250°C,
15 preferably 30°C to 200°C, and peroxyester levels (on a pure base) of 0.002 to 3%, preferably 0.002 to 1% by weight based on monomer, are employed in polymerizations or copolymerizations of ethylenically unsaturated monomers.

The hydroxy-t-alkyl peroxyesters A of this invention can
20 also be used in combination with other free-radical initiators such as peroxy sters which include t-butyl peroxy-pivalate, t-butyl peroxy-2-ethylhexanoate, t-butyl peroxyacetat , t-amyl peroxy-pivalate, t-butyl peroxyneodecanoate, t-amyl per xyneodecanoate, 1,1,3,3-tetramethyl-
25 butyl peroxyneodecanoate and alpha-cumyl peroxyneodecan ate;

dialkyl peroxydicarbonates including di- n-propyl, diisopropyl, di-(sec-butyl), dicyclohexyl, di-(4-t-butyl-cyclohexyl), di-(2-phenoxyethyl), di-(2-ethylhexyl) and dihexadecyl peroxydicarbonates; acyl alkylsulfonyl peroxides including acetyl cyclohexylsulfonyl peroxide and acetyl sec-heptylsulfonyl peroxide; diacyl peroxides including dibenzoyl peroxide, didodecyl peroxide, diisobutyryl peroxide and di-(2-methylpentanoyl) peroxide; diperoxyketals including 2,2-di-(t-butylperoxy)butane, 2,2-di-(t-butylperoxy)-heptane, ethyl 3,3-di-(t-butylperoxy)butyrate, 1,1-di-(t-butylperoxy)-3,3,5-trimethylcyclohexane, 1,1-di-(t-butylperoxy)cyclohexane and 1,1-di(t-amylperoxy)-cyclohexane; monoperoxycarbonates including OO-t-butyl O-isopropyl monoperoxycarbonate and OO-t-butyl O-(2-ethylhexyl) monoperoxycarbonate; dialkyl peroxides such as 2,5-dimethyl-2,5-di-(t-butylperoxy)hexane; and azo compounds including azobis(isobutyronitrile), 2-t-butylazo-2-cyano-4-methoxy-4-methylpentane and 1-t-butylazo-1-cyano-cyclohexane.

20

Curing of Unsaturated Polyester Resins

In the curing of unsaturated polyester resin compositions by heating at suitable curing temperatures in the presence of free-radical curing agents, the hydroxy-t-alkyl per xyesters A of this invention exhibit enhanced

curing activity. Unsaturated polyester resins that can be cured by the peroxides of this invention usually includes an unsaturated polyester and one or more polymerizable monomers.

The unsaturated polyesters are, for instance, polyesters
5 as they are obtained by esterifying at least one ethylenically unsaturated di- or polycarboxylic acid, anhydride or acid halide, such as maleic acid, fumaric acid, glutaconic acid, itaconic acid, mesaconic acid, citraconic acid, allylmalonic acid, allylsuccinic acid, tetrahydrophthalic
10 acid and others with saturated or unsaturated di- or polyols, such as ethylene glycol, diethylene glycol, triethylene glycol, 1,2- and 1,3-propanediols, 1,2- 1,3- and 1, 4-butanediols, 2,2-dimethyl-1,3-propanediol, 2-hydroxy-methyl-2-methyl-1,3-propanediol, 2-buten-1,4-diol, 2-
15 butyn-1,4-diol, 2,2,4-trimethyl-1,3-pentanediol, glycerol, pentaerythritol, mannitol and others. Mixtures of such polyacids and/or mixtures of such polyalcohols may also be used. The unsaturated di- or polycarboxylic acids may be partially replaced, by saturated polycarboxylic acids, such
20 as adipic acid, succinic acid, sebacic acid and others and/or by aromatic polycarboxylic acids, such as phthalic acid, trimellitic acid, pyromellitic acid, isophthalic acid and terephthalic acid. The acids used may be substituted by groups such as halogen. Examples of such suitable
25 halogenated acids are, for instance, tetrachlorophthalic acid, 5,6-dicarboxy-1,2,3,4,7,7-hexachlorobicyclo(2.2.1)-2-

heptene and others.

The other component of the unsaturated polyester resin composition, the polymerizable monomer or monomers, can be preferably ethylenically unsaturated monomers, such as
5 styrene, chlorostyrene, vinyltoluene, divinylbenzene, alpha-methylstyrene, diallyl maleate, diallyl phthalate, dibutyl fumarate, acrylonitrile, triallyl phosphate, triallyl cyanurate, methyl acrylate, methyl methacrylate, n-butyl methacrylate, ethyl acrylate and others, or mixtures thereof,
10 which are copolymerizable with said polyesters.

A preferred resin composition contains as the polyester component the esterification product of 1,2-propylene glycol (a polyalcohol), maleic anhydride (an anhydride of an unsaturated polycarboxylic acid) and phthalic anhydride (an
15 anhydride of an aromatic dicarboxylic acid) as well as the monomer component, styrene.

Temperatures of about 20°C to 200°C and peroxide levels of about 0.05% to 5% or more by weight of curable unsaturated polyester resin are normally employed.

20 The unsaturated polyesters described above can be filled with various materials such as sulfur, glass fibers, carbon blacks, silicas, metal silicates, clays, metal carbonates, antioxidants, heat and light stabilizers, sensitizers, dyes, pigments, accelerators, metal oxides such as zinc oxide,
25 blowing agents, etc.

Other types of unsaturated resins can be cured using the compositions of this invention as curing catalysts. These resins, called unsaturated vinyl ester resins, consist of a vinyl ester resin component and one or more polymerizable monomer components. The vinyl ester resin component can be made by reacting a chloroepoxide such as epichlorohydrin with appropriate amounts of a glycol such as bisphenol A [2,2-di-(4-hydroxyphenyl)propane], in the presence of a base such as sodium hydroxide, to yield a condensation product having terminal epoxy groups derived from epichlorohydrin. Subsequent reaction of the condensation product with polymerizable unsaturated carboxylic acids such as acrylic acid and methacrylic acid, in the presence or absence of acidic or basic catalysts, results in formation of a vinyl ester terminated resin component. Normally styrene is added as the polymerizable monomer component to complete the preparation of the unsaturated vinyl ester resin.

Temperatures of about 20°C to 200°C and pure peroxide levels of about 0.05% to 5% or more by weight of curable unsaturated vinyl ester resin compositions are normally employed for curing of the unsaturated vinyl ester resins.

The unsaturated vinyl ester resin described above can be filled with the materials employed with the unsaturated polyester resin compositions described previously.

The hydroxy-g-alkyl peroxyesters A of this invention

can also be employed for curing of monomers such as diethylene glycol bis(allyl carbonate)(ADC) as well as other diallyl and polyallyl compounds. In these applications 0.1 to 10% or more of the invention peroxyesters, based on
5 curable monomer, can be employed. Temperature profiles are usually employed in the ADC curing processes. The temperatures range from about 70°C initially to about 125°C and the time for curing can range up to 10 hours.

The hydroxy-t-alkyl peroxyesters A of this invention can
10 also be used as intermediates to prepare other peroxides by reaction at the hydroxy group.

EXAMPLES

Neohexanoyl chloride and other acid chlorides used in the preparations of the hydroxy-t-alkyl peroxyesters of this
15 invention, prior art peroxyesters, and other peroxyesters prepared in the examples were prepared by procedures similar to that outlined in Example I of U.S. Patent 3,624,123.

3-Hydroxy-1,1-dimethylbutyl hydroperoxide was prepared according to the procedure outlined in Example 2 of U.S.
20 Patent 3,236,872. 7-Hydroxy-1,1,5-trimethylheptyl hydroperoxide was similarly prepared.

The starting material, 3-hydroxy-1,1-dimethylpropyl hydroperoxide, was prepared using a procedure similar for preparing 3-hydroxy-1,1-dimethylbutyl hydroperoxide, mentioned
25 above; this compound was prepared from 3-methyl-3-buten-1-ol (0.50 mole) and 50% H₂O₂ (2.00 moles) with concentrated

The product that was isolated was a liquid having an assay of 81.2% according to hydroperoxide active oxygen content. The corrected yield was 37.9%.

EXAMPLE 1

5 Preparation of 3-Hydroxy-1,1-dimethylbutyl Peroxypivalate (I-1)

A jacketed reactor equipped with a mechanical stirrer, a thermometer and a dropping funnel was charged with 19.9 g (0.160 mole) of 45% KOH, 9.9 g of water, 21.5 g (0.150 mole) of 93.7% 3-hydroxy-1,1-dimethyl butyl hydroperoxide (also
10 known as 4-hydroxy-2-methyl-2-hydroperoxypentane), 25 g of methylene chloride and 0.65 g (0.002 mole) of tetrabutyl-ammonium bromide, a phase transfer catalyst (PTC). The resulting vigorously stirred mixture was cooled to -5 to -2°C and to it was slowly added 12.6 g (0.100 mole) of 95.4%
15 pivaloyl chloride over a period of about 30 minutes. The resulting product mixture was then stirred for 2 hours at -5 to -2°C after which 25 g of 10% KOH and an additional 50 g of methylene chloride were added to the reaction mixture. The reaction mass was allowed to separate into two liquid phases
20 at 10°C and the lower organic layer was removed, dried over about 5% by weight of anhydrous $MgSO_4$ and after the spent desiccant was separated by filtration the methylene chloride was removed in vacuo at 0 to 10 C. Obtained was 24.5 g of liquid product which had an assay of 72.3% according to
25 peroxyester active oxygen content. The corrected yield was

81.3%. An infrared spectrum of the product showed a large broad OH band centered at 3450 to 3550 cm^{-1} .

EXAMPLE 2

Preparations of Other 3-Hydroxy-1,1-dimethylbutyl Peroxyesters

5 The procedure utilized in Example 1 was employed for preparation of other 3-hydroxy-1,1-dimethylbutyl peroxyesters from 3-hydroxy-1,1-dimethylbutyl hydroperoxide and various carboxylic acid chlorides. The starting carboxylic acid chloride, the conditions employed and the yield data for
10 these preparations are summarized in Table I. Also included in Table I are the results for Example 1. In all cases, the infrared spectrum of the product exhibited a strong and broad OH band centered at about 3400 to 3500 cm^{-1} which showed that the desired product
15 was obtained.

Decomposition studies in dilute solution showed that 3-hydroxy-1,1-dimethylbutyl peroxyneodecanoate (I-3) had a 10
hour half-life temperature (i.e., the temperature at which half of the peroxide is decomposed in 10 hours) in trichloroethylene of 36°C and that 3-hydroxy-1,1-dimethylbutyl
20 peroxy-(2-ethylhexanoate)(I-6) had a 10 h ur half-life temperature in benzene of about 66 to 67°C.

TABLE I

3-Hydroxy-1,1-Dimethylbutyl Peroxyesters

droxy-1,1-Dimethyl- 1 peroxyest r	Acid Chloride Employed	Peroxidation Conditions Temp. °C Time, hrs	PTC	Assay, %	Corr. Yield, %	Infrared OH Band, cm ⁻¹
xypivalate (I-1)	pivaloyl	-5 to -2	TEABr ^a	72.3	81.3	broad, 3450-3550
xyneohexanoat (I-2)	Neohexanoyl	0 to 5	No	80.5	79.8	broad, 3450-3550
xyneohexanoate (I-2)	Neohexanoyl	0 to 5	TEABr ^a	77.9	90.7	broad, 3450-3550
xyneodecanoate (I-3)	Neodecanoyl	28 to 30	No	79.3	78.5	broad, 3450-3550
xyneodecanoate (I-3)	Neodecanoyl	28 to 30	TEABr ^a	81.8	73.8	broad, 3450-3550
xyneodecanoat (I-4)	Neotridecanoyl	28 to 30	No	67.5	73.7	medium, 3500
xyisobutyrate (I-5)	Isobutyryl	30	No	80.2	56.6	broad, 3400-3500
xy-2-ethyl- oate (I-6)	2-Ethylhexanoyl	10 to 15	No	85.6	84.3	sharp, 3550
xy-2-ph nyl- rate (I-7)	2-Phenylbutyryl	10 to 15	No	74.1	50.0	-

^a TEABr - Tetraabutylammonium Bromide, Phase Transfer Catalyst (PTC)

For the sake of comparison, some of the next adjacent homologue compounds where the atomic distance (as measured by intervening atoms) between the hydroxyl function and the peroxyester function is increased by a carbon atom were prepared as follows:

Preparation of 7-Hydroxy-1,1,5-trimethylheptyl Peroxypivalate (C-1)

A jacketed reactor equipped with a mechanical stirrer, a thermometer and a dropping funnel was charged with 9.3 g (0.075 mole) of 45% KOH, 4.7 g of water and 11.3 g (0.058 mole) of 97.3% 7-hydroxy-1,1,5-trimethylheptyl hydroperoxide. To this vigorously stirred solution at 30°C was slowly added 6.4 g (0.050 mole) of 94.3% pivaloyl chloride over a period of 20 minutes. The resulting mixture was then vigorously stirred for one hour at 30°C after which it was cooled to 15°C and 100 ml of pentane and 25 ml of water were added. After separating and discarding the aqueous phase the product solution was washed at 10 to 15°C with 20 g of buffered sodium sulfite solution (consisting of 0.8 g of acetic acid, 1.2 g of sodium acetate, 2.0 g of sodium sulfite and 16 g of water), with 15 ml of water and then with 20 g of 7.7% sodium hydrogen carbonate solution. The resulting pentan solution was then dried over anhydrous MgSO_4 and after separation of the spent desiccant by filtration the pentane was removed in vacuo at 0 to 10°C leaving 8.2 g of liquid product.

The assay of the product according to peroxyester active oxygen was 69.6% and the corrected yield was 41.7%.

An infrared spectrum of the product showed a strong, broad OH band centered at 3400 to 3500 cm^{-1} .

5 Preparation of 7-Hydroxy-1,1,5-trimethylheptyl Peroxyneodecanoate
(C-2)

The same procedure as used in the preparation of C-1, supra, was employed for the preparation of 7-hydroxy-1,1,5-trimethylheptyl peroxyneodecanoate using as the starting materials 7-hydroxy-1,1,5-trimethylheptyl hydroperoxide and neodecanoyl chloride. The liquid product was obtained in 84.3% assay and 72.5% corrected yield. An infrared spectrum of the product showed a strong, broad OH band centered at 3400 to 3500 cm^{-1} .

15 Preparation of 7-Hydroxy-1,1,5-trimethylheptyl Peroxyneohexanoate
(C-3)

Employing the reactants 7-hydroxy-1,1,5-trimethylheptyl hydroperoxide and neohexanoyl chloride and using the same procedure as used for the preparation of C-1, the title peroxyester, 7-hydroxy-1,1,5-trimethylheptyl peroxyneohexanoate, was prepared in an assay of 86.1% and a corrected yield of 71%. An infrared spectrum of the product showed a very large OH band centered at about 3450 cm^{-1} .

Preparation of 7-Hydroxy-1,1,5-trimethylheptyl Peroxy-
(2-Ethylhexanoate) (C-4)

The title peroxyester, 7-hydroxy-1,1,5-trimethylheptyl peroxy-(2-ethylhexanoate), was prepared in an assay of 88.7% and a corrected yield of 78.0% by using the procedure employed in the preparation of C-1 using as reactants 7-hydroxy-1,1,5-trimethylheptyl hydroperoxide and 2-ethylhexanoyl chloride. An infrared spectrum of the product showed a moderate OH band centered at about 3450 to 3500 cm^{-1} .

Preparation of 4-Hydroxy-1,1,4,4-Tetramethylbutyl Peroxypivalate
(C-5)

A jacketed reactor equipped with a mechanical stirrer, a thermometer and a dropping funnel was charged with 18.7 g (0.150 mole) of 45% KOH, 15.0 g of water, 27.6 g (0.120 mole) of 77.6% (wetted solid) 2,5-dimethyl-2,5-dihydroperoxyhexane and 100 ml of methylene chloride. To the resulting two liquid phase mixture at 28 to 30°C was added 12.8 g (0.100 mole) of 94.3% pivaloyl chloride over a period of about 30 minutes. The resulting mixture was then stirred for 2.0 hours at 28 to 30°C after which the mixture was cooled to 15 to 20°C and was allowed to separate into phases. The upper aqueous layer was removed and was discarded. The resulting product solution was then washed with 50 ml of 20% KOH solution at 0°C and then with 50 ml

of 7.7% sodium hydrogen carbonate solution at 15 to 20°C. The methylene chloride solution was then cooled to 0 to 10°C and was reacted with 187 g of buffered sodium sulfite solution (consisting of 7.6 g of acetic acid, 8.4 g of sodium acetate, 19 g of sodium sulfite and 152 g of water) in order to convert the 4-hydroperoxy-1,1,4,4-tetramethylbutyl peroxy-pivalate that was formed in the peroxidation reaction to 4-hydroxy-1,1,4,4-tetramethylbutyl peroxy-pivalate, the desired product. A thick emulsion resulted which required three days of storage in the refrigerator to separate into two liquid phases. The upper aqueous layer was removed and an equal volume of diethyl ether was added in order to facilitate further processing. The solution was dried over anhydrous MgSO_4 and after separation of the spent desiccant by filtration the solvents were removed in vacuo at 0 to 10°C. Some solids were removed by filtration and the resulting liquid weighed 20.4 g. The assay of the product was 90.3% according to peroxyester active oxygen content. The corrected yield was 74.9%. An infrared spectrum of the product showed a broad OH band centered at 3300 to 3400 cm^{-1} .

Preparation of 4-Hydroxy-1,1,4,4-Tetramethylbutyl Peroxynodecanoate (C-6)

Reacting neodecan yl chloride with 2,5-dimethyl-2, 5-dihydroperoxyhexane followed by reducing the intermediate product with a buffered sodium sulfite solution employing

the same procedure as used in preparation of C-5 resulted in the preparation of 4-hydroxy-1,1,4,4-tetramethylbutyl peroxyneodecanoate. The liquid product had an assay of 91.7% and was obtained in a corrected yield of 55.1%.

- 5 An infrared spectrum of the product showed a broad OH band centered at 3300 to 3500 cm^{-1} .

EXAMPLE 3

Preparation of 3-Hydroxy-1,1-Dimethylpropyl Peroxyneodecanoate (I-8)

- 10 The procedure employed for preparation of 3-hydroxy-1, 1-dimethylbutyl peroxyneodecanoate in Example 2 (without the PTC) was used in this example for preparing 3-hydroxy-1,1-dimethylpropyl peroxyneodecanoate from neodecanoyl chloride and 3-hydroxy-1,1-dimethylpropyl hydroperoxide. The assay
15 of the product was 66.0% according to peroxyester active oxygen content and the correct yield was 65.1%. The infrared spectrum showed a broad OH band centered at 3350 to 3450 cm^{-1} .

Example 4

- 20 Preparation of 3-Hydroxy-1,1-Dimethylpropyl Peroxyneohexanoate (I-9)

- The procedure employed for preparation of 3-hydroxy-1, 1-dimethylbutyl peroxyneohexanoate in Example 2 (without the PTC) was used in this example for preparing 3-hydroxy-1,
25 1-dimethylpropyl peroxyneohexanoate from neohexanoyl chloride

and 3-hydroxy-1,1-dimethylpropyl hydroperoxide. The assay of the product was 54.3% according to peroxyester active oxygen content and the corrected yield was 42.7%. An infrared spectrum of the product showed a broad OH band centered at 3400 to 3450 cm^{-1} .

EXAMPLE 5

Vinyl Chloride suspension Polymerizations Employing Hydroxy-t-Alkyl Peroxyesters as Free-Radical Initiators

Several hydroxy-t-alkyl peroxyesters of the instant invention were comparatively evaluated with art t-butyl peroxyesters derived from the same carboxylic acids in vinyl chloride suspension polymerizations at 50°C and 55°C. The vinyl chloride suspension polymerization procedure that was employed is described below.

Suspension Polymerizations

Polymerizations of vinyl chloride in suspension were carried out in a 1.5 liter reactor, which was designed and instrumented such that the polymerization could be monitored calorimetrically. The reactor was immersed in a water bath, maintained 0.5°C above the desired reaction temperature, thus preventing any heat loss to the surroundings. The heat produced from the exothermic polymerization plus the heat passed into the reactor from the water bath were removed by the passage of cooling water through internal coils in the reactor. Thus, the temperature was kept constant. The flow rate of the cooling water and the temperature difference

between entrance and exit streams were monitored, thus producing a continuous recording of heat removed (cal. min^{-1}).

The pressure in the reactor was also continuously monitored. At about 70% conversion of monomer to polymer, the monomer in the vapor phase became depleted and the pressure fell. Thus, from a knowledge of the point of 70% conversion and the heat of polymerization of vinyl chloride (23 Kcal/mole), it was possible to calculate the "background count" in the calorimetric recording; this background was due to heat flow from the water bath to the reactor. By subtraction, the true rate of polymerization (cal. min^{-1}), as function of time, was obtained.

In the polymerization the following sequence of operations was followed:

- 1) The reactor was assembled and tested for leaks.
- 2) The water bath around the reactor was heated to 0.5°C above the desired reaction temperature.
- 3) The cooling water bath was heated to 10°C less than the reaction temperature.
- 4) The aqueous phase plus suspending agents (described later) was heated to 10°C above the desired reaction temperature, and charged into the reactor.
- 5) The initiator compositions were added and the filling port sealed.

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- 6) The reactor was evacuated by the use of a water aspirator.
- 7) The vinyl chloride (200g) was added, by displacement with nitrogen, from a small cylinder, the reactor was
5 pressurized with nitrogen to about 150 psi (guage). The addition of the cold vinyl chloride reduced the temperature of the aqueous phase to a point close to the desire reaction temperature.
- 8) Stirring was commenced.
- 10 9) The reactor controllers were switched on beginning automatic control of the temperature and continuous recording of heat output and pressure.
- 15 10) After the pressure drop was observed, the pressure, temperature and heat of polymerization were further monitored for another one to two hours. The reactor data after the pressure drop were then used to determine the rate of pressure drop, $\Delta P / \Delta t$. The $\Delta P / \Delta t$ was an
important value since it was a measure of the rate of polymerization after onset of the pressure drop. The
20 larger the absolute value of $\Delta P / \Delta t$ the higher the rate of polymerization after the pressure drop and the higher the percent conversion of vinyl chloride monomer to
polyvinyl chloride. After these data were obtained, the remaining vinyl chloride and nitrogen were vented
25 and the reactor dismantled for cleaning.

Suspension System Used (pH ~ 6.5)

1% solution of Aerosol MA 80%* 42 ml

1% solution of Methocel F 50** 168 ml

Triply distilled water 469 ml

5 *Surfactant made by American Cyanamid Co. (sodium dihexyl sulfosuccinate)

**Hydroxypropyl methyl cellulose polymer made by Dow Chemical.

10 Note: pH of the aqueous phase was measured at ambient temperatures, 22°C, using a standard pH meter.

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TABLE II

Vinyl Chloride Suspension Polymerization
Efficiencies of Hydroxy-t-alkyl Peroxyesters

Peroxyester Employed	Peroxyester Level P/HPM ¹ MOLES/HGM ²	Polymer Conditions Temp., °C pH	Time to Press. Drop, MINS	Rate of Press. Drop $\frac{\Delta P}{\Delta t}$, psi/M
I-1	0.075 3.44 x 10 ⁻⁴	55 ~6.5	230	-12
A-1	0.060 3.44 x 10 ⁻⁴	55 ~6.5	440	-18
I-2	0.119 5.12 x 10 ⁻⁴	55 ~6.5	170	-44
A-2	0.096 5.10 x 10 ⁻⁴	55 ~6.5	250	-20
A-3	0.104 5.14 x 10 ⁻⁴	55 ~6.5	240	-24
I-3	0.125 4.33 x 10 ⁻⁴	55 ~6.5	180	NA*
I-3	0.099 3.42 x 10 ⁻⁴	50 ~6.5	310	NA*
A-4	0.125 5.11 x 10 ⁻⁴	55 ~6.5	270	-15 to -17
A-5	0.132 5.11 x 10 ⁻⁴	55 ~6.5	240	-17
C-3	0.148 5.13 x 10 ⁻⁴	55 ~6.5	300	-26
C-5	0.091 3.48 x 10 ⁻⁴	55 ~6.5	>450 ³	NA*

* NA - not available.

1. P/HPM - Parts per hundred parts monomer.

2. MOLES/HGM - Moles per hundred grams monomer.

3. No pressure drop observed up to 450 minutes.

Table II summarizes the times that were required for reaching the onset of pressure drop [ca. 70% conversion of vinyl chloride monomer to polyvinyl chloride (PVC)] and the rate of pressure drop ($\Delta P/\Delta t$) after onset of the pressure drop when the hydroxy-t-alkyl peroxyesters of this invention, i.e., 3-hydroxy-1,1-dimethylbutyl peroxy-pivalate (I-1), 3-hydroxy-1,1-dimethylbutyl peroxyneohexanoate (I-2) and 3-hydroxy-1,1-dimethylbutyl peroxyneodecanoate (I-3), were evaluated and compared to the corresponding t-alkyl peroxyesters of the prior art, i.e., t-butyl peroxy-pivalate (A-1), t-butyl peroxyneohexanoate (A-2), t-amyl peroxyneohexanoate (A-3), t-butyl peroxyneodecanoate (A-4) and t-amyl peroxyneodecanoate (A-5). The time to pressure drop results unexpectedly and surprisingly showed that the hydroxy-t-alkyl peroxyesters of this invention (e.g. I-1, I-2 and I-3) were significantly more efficient on an equal molar basis than were the corresponding t-alkyl peroxyesters of the prior art (e.g., A-1, A-2, A-3, A-4, and A-5, respectively). These results significantly advance the peroxide and the vinyl chloride polymerization art, since hydroxy-t-alkyl peroxyesters of the instant invention are required in significantly lesser amounts than are the corresponding prior art t-alkyl peroxyesters. This means that a PVC producer would not only use significantly less of the hydroxy-t-alkyl peroxyesters of this invention for producing the same amount of PVC (see results in Table II

for I-3 vs. A-4 and A-5) but he would also have to store less of the invention hydroxy-t-alkyl peroxyesters in his refrigerated storage facilities. Therefore, the initiator costs to the PVC producer would be considerably reduced if the PVC producer were to employ the more active hydroxy-t-alkyl peroxyesters of this invention for polymerizing vinyl chloride.

Table II also summarizes vinyl chloride suspension efficiency data for two other hydroxy-t-alkyl peroxyesters, 7-hydroxy-1,1,5-trimethylheptyl peroxyneohexanoate (C-3) and 4-hydroxy-1,1,4,4-tetramethylbutyl peroxy-pivalate (C-5). Comparing the efficiency of invention hydroxy-t-alkyl peroxyester I-2 with that of C-3 and the efficiency of invention hydroxy-t-alkyl peroxyester I-1 with that of C-5, the efficiencies of invention hydroxy-t-alkyl peroxyester I-1 and I-2 were significantly better than were those of C-5 and C-3, respectively. Hence, these results demonstrated the criticalness that the invention hydroxy-t-alkyl peroxyesters must have one carbon atom between the $R-C(=O)-O-C(CH_3)_2-$ group and the $HO-CR_3R_4-$ group. If two carbons (e.g., C-5) or five carbons (e.g., C-3) are present, the resulting hydroxy-t-alkyl peroxyesters are significantly less efficient than the invention hydroxy-t-alkyl peroxyesters (e.g., I-1 and I-2).

Example 6SPI Exotherms of the Hydroxy-t-Alkyl Peroxyesters of this Invention

The unsaturated polyester resin in this example was a
5 mixture of an unsaturated polyester and styrene monomer. The unsaturated polyester was an alkyd resin made by esterifying the following components:

	<u>Component</u>	<u>Quantity</u>
	Maleic anhydride	1.0 mole
10	Phthalic anhydride	1.0 mole
	Propylene glycol	2.2 moles

To the resulting resin was added 0.013% by weight of hydroquinone inhibitor. The alkyd resin had an Acid No. of 45-50. Seven (7) parts by weight of the above polyester
15 (alkyd resin) were diluted with three (3) parts by weight of monomeric styrene. The resulting unsaturated polyester resin had the following properties:

- a. Viscosity (Brookfield No. 2 at 20 r.p.m.) 13.0 poise
- b. Specific gravity 1.14

20 Curing Procedure

Gelation and cure characteristics of various initiators in the above unsaturated polyester resin were determined using the Standard SPI Exotherm Procedure ("SPI Procedure for Running Exotherm Curves-Polyester Resins", published in the
25 Preprint of the 16th Annual Conference - Reinforced Plastics Division, Society of the Plastics Industry, Inc. February

1961). Using the procedure at 82°C several hydroxy-t-alkyl peroxyesters of this invention were evaluated and compared to the results employing prior art t-alkyl peroxyesters derived from the same carboxylic acids. The results are summarized in Table III and show that the hydroxy-t-alkyl peroxyester of this invention, I-1, I-2 and I-3, are more active than the corresponding t-butyl peroxyesters A-1, A-2 and A-4, respectively, of the art as judged by significantly shorter cure times.

Table III
82° C SPI Exotherm Data for
Hydroxy-t-Alkyl Peroxyesters
 (1.0% by weight of pure peroxide used)

	Curing Catalyst	Gel, Mins	Cure, Mins	Peak Exotherm, ° F	Barcol Hardness
5					
10	3-Hydroxy-1,1-dimethyl- butyl Peroxypivalate (I-1)	0.10	1.05	373	45-50
	t-Butyl Peroxypivalate (A-1)	0.50	1.30	398	45-50
15	3-Hydroxy-1,1-dimethyl- butyl Peroxyneohexa- noate (I-2)	0.20	1.00	396	45-50
	t-Butyl Peroxyneohexan- oate (A-2)	0.20	1.40	369	45-50
20	3-Hydroxy-1,1-dimethyl- butyl Peroxyneode- canoate (I-3)	0.15	1.00	376	45-50
	t-Butyl Peroxyneode- canoate (A-4)	0.20	1.30	370	45-50

Example 782°C SPI Exotherms of the Hydroxy-t-Alkyl Peroxyesters of this Invention Compared to Art Peroxyesters

The unsaturated polyester resin and the procedure used
5 in this example were those employed in Example 6. The prior art compounds, 3-benzoyloxy-1,1-dimethylbutyl peroxybenzoate (A-6) of U.S. Pat. 3,236,872 and 4-(3-hydroxy-1,1-dimethyl-butyl-peroxycarbonyl)-3-hexyl-6-[7-(3-hydroxy-1,1-dimethyl-butylperoxycarbonyl)heptyl] cyclohexene (A-7) of U.S. Pat.
10 4,079,074, were prepared according to the procedures outlined in the Prior art references. Although the 3-hydroxy-1,1-dimethyl-butyl peroxyesters of this invention can be prepared without appreciable contamination by the corresponding ester-peroxyester (Structure C, infra) by reacting 3-hydroxy-1,1-
15 dimethylbutyl hydroperoxide with the corresponding acid chloride, the 3-hydroxy-1,1-dimethylbutyl peroxyesters could not be prepared from 3-hydroxy-1,1-dimethylbutyl hydroperoxide and aromatic acid chlorides. In particular, attempts to prepare 3-hydroxy-1,1-dimethylbutyl
20 peroxybenzoate (A-8) from 3-hydroxy-1,1-dimethylbutyl hydroperoxide and benzoyl chloride produced very little of the desired product, A-8. Instead, the product was mostly A-6 which meant that benzoyl chloride reacts too readily with the HO- group of 3-hydroxy-1,1-dimethylbutyl
25 hydr peroxide and the HO- group f A-8. On the other hand

the acid chlorides that are used in the processes for producing the instant invention peroxyesters surprisingly react significantly less readily with the HO-group of 3-hydroxy-1,1-dimethylbutyl

5 hydroperoxide and the HO- group of the 3-hydroxy-1,1-dimethylbutyl peroxyesters of this invention. Thus, the hydroxy-t-alkyl peroxyesters A of this invention are the dominant reaction products.

The following Table IV summarizes the 82° C (180° F) SPI
10 exotherm data when 1.0% by pure weight of various peroxyesters were used to cure the unsaturated polyester resin. The invention peroxyesters employed were 3-hydroxy-1,1-dimethylbutyl peroxy-(2-ethylhexanoate) (I-6) and 3-hydroxy-1,1-dimethylbutyl peroxyneohexanoate (I-2)
15 whereas the prior art compounds evaluated were A-6, A-7, t-butyl peroxy-(2-ethylhexanoate) (A-9) and t-butyl peroxybenzoate (A-10).

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Table IV
82°C (180°F) SPI Exotherm Data
 (1% By weight of Pure Peroxyester)

	Peroxyester	Gel, Mins	Cure, Mins	Peak Exotherm, °F	Barcol Hardness
5	I-2	0.2	1.0	386	45-50
	I-6	1.6	2.4	382	40-50
	A-9	5.5	6.7	388	45-50
10	A-7	11.5	14.5	375	33-45
	A-6	40.4	53.4	294	0-40
	A-10	No Gel up to 50 minutes			

The results in Table IV show that the invention 3-hydroxy-1,1-dimethylbutyl peroxyesters of this invention (i.e., I-2 and I-6) were significantly more active in the unsaturated polyester resin than were the art peroxyesters as judged by shorter gel and cure times and/or by enhanced hardness [compare the results for invention peroxyester I-6 with those for prior art peroxyesters A-9, A-7, A-6 and A-10].

What is Claim:

1. A hydroxy-t-alkyl peroxyester of the structure



having a ten half-life temperature below about 75°C, where

R₁ and R₂ are selected from an alkyl of 1 to 4 carbons,

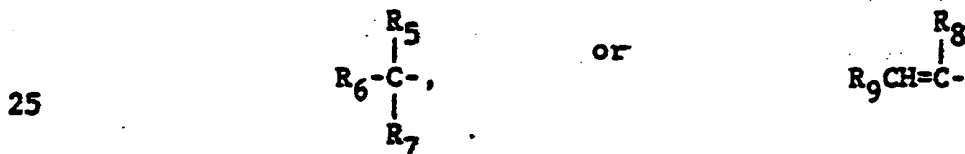
10 R₃ and R₄ are selected from hydrogen or an alkyl of 1 to 4 carbons,

R₁ and R₃ can be connected together to form a lower alkyl substituted 3 carbon atom alkylene bridge and R₂ can additionally be



20 and

R is selected from



wh re

R₅ is selected from hydr gen or an alkyl of 1 to 8 carbons,

R_6 is selected from alkyl of 1 to 8 carbons,

R_7 is selected from the group consisting of an alkyl of 1 to 8 carbons, an alkenyl of 1 to 8 carbons, an aryl of 6 to 10 carbons, an alkoxy of 1 to 6 carbons and an aryloxy of 6 to 10 carbons, and

R_8 and R_9 are selected from an alkyl of 1 to 4 carbons.

2. The hydroxy-t-alkyl peroxyester of Claim 1 where R_1 , R_2 and R_3 are methyl and R_4 is hydrogen.

3. The hydroxy-t-alkyl peroxyester of Claim 1 wherein said peroxyester is selected from the group consisting of
3-hydroxy-1,1-dimethylbutyl peroxypivalate,
3-hydroxy-1,1-dimethylbutyl peroxyneohexanoate,
3-hydroxy-1,1-dimethylbutyl peroxyneodecanoate, 3-hydroxy-1,1-dimethylbutyl peroxyneotridecanoate,
3-hydroxy-1,1-dimethylbutyl peroxyisobutyrate, 3-hydroxy-1,1-dimethylbutyl peroxy-2-ethylhexanoate, 3-hydroxy-1,1-dimethylbutyl peroxy-2-phenylbutyrate, 3-hydroxy-1,1-dimethylpropyl peroxyneodecanoate, and 3-hydroxy-1,1-dimethylpropyl peroxyneohexanoate.

4. A process of polymerizing ethylenically unsaturated monomers comprising adding to the reaction mass of said monomers an initiating amount of the hydroxy-t-alkyl

peroxyester of Claim 1 as the initiator and polymerizing said reaction mass until completion.

5. The process of Claim 4 wherein the ethylenically unsaturated monomer is vinyl chloride or ethylene.

5 6. The process of Claim 5 wherein the initiator for polymerizing vinyl chloride monomer is selected from the group consisting of 3-hydroxy-1,1-dimethylbutyl peroxy-pivalate, 3-hydroxy-1,1-dimethylbutyl peroxyneohexanoate, and 3-hydroxy-1,1-dimethylbutyl peroxyneodecanoate.

10 7. A process of curing an unsaturated polyester resin composition comprising adding to the reaction mass of said unsaturated polyester resin composition a catalyzing amount of the hydroxy-t-alkyl peroxyester of Claim 1 as the curing agent and heating the reaction mass until completion.

15 8. The process of Claim 7 wherein the curing catalyst is selected from the group consisting of 3-hydroxy-1,1-dimethylbutyl peroxy-pivalate, 3-hydroxy-1,1-dimethylbutyl peroxyneohexanoate, 3-hydroxy-1,1-dimethylbutyl peroxyneodecanoate, and 3-hydroxy-1,1-dimethylbutyl
20 peroxy-2-ethylhexanoate.